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Regeneration in Mixed Conifer Partial Cuttings in the Blue Mountains of Oregon and Washington

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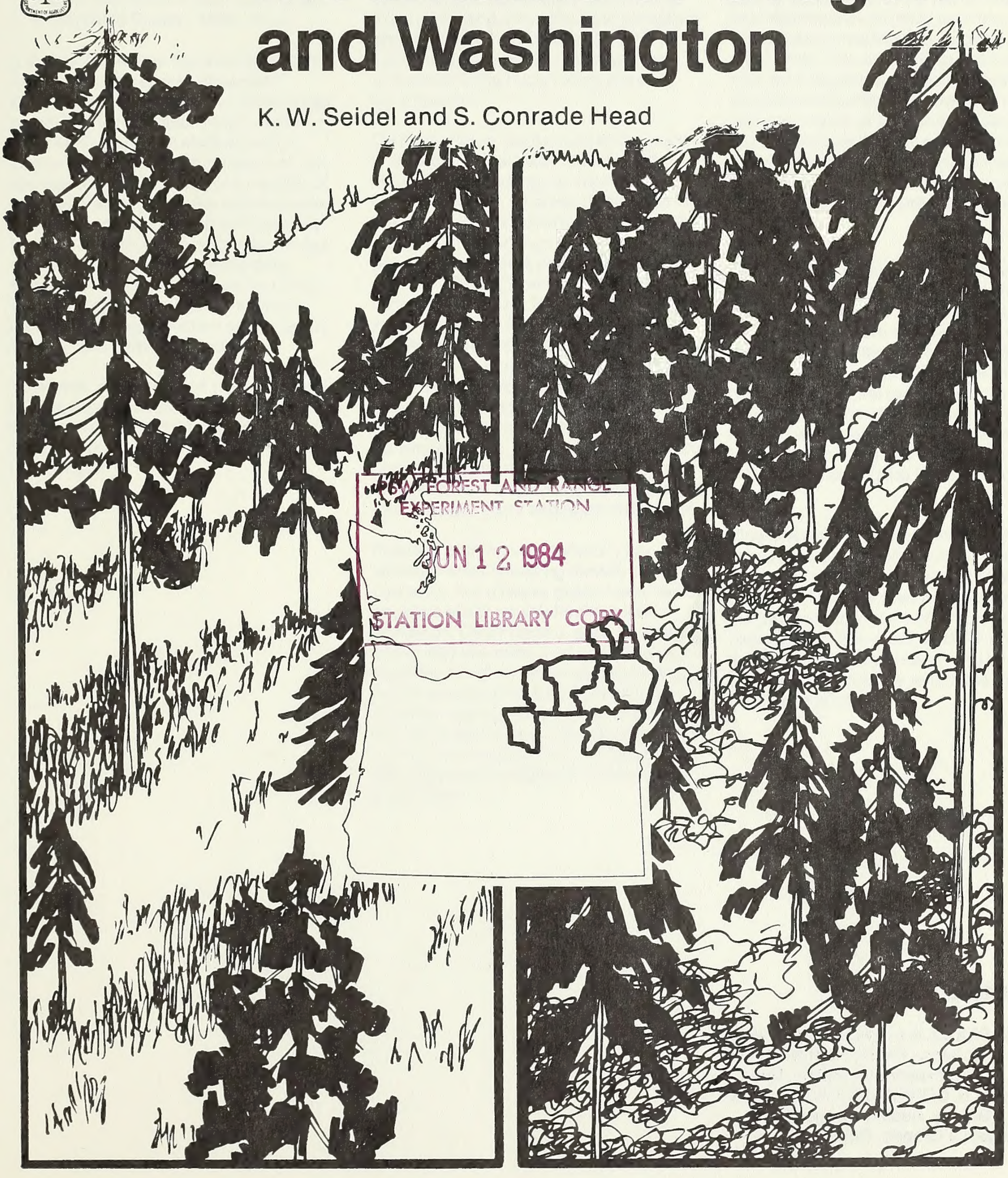

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Abstract

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A survey in the Blue Mountains of northeastern Oregon and southeastern Washington showed that, on the average, partial cuts in the grand fir/big huckleberry community were well stocked with a mixture of advance, natural postharvest, and planted reproduction of a number of species. Partial cuts in the mixed conifer/pinegrass community had considerably fewer seedlings; some plots were understocked. Much of the understocking appeared to be related to low and irregular overstory density, lack of advance reproduction, reproduction destroyed by logging, and heavy grass cover.

Keywords: Regeneration (stand), partial cutting, regeneration (artificial), regeneration (natural), mixed stands, Blue Mountains (Oregon), Blue Mountains (Washington).

Research Summary

Regeneration of partial cuts in mixed conifer forests at midelevation in the Blue Mountains of northeastern Oregon and southeastern Washington was surveyed to determine the status of reforestation and to identify key environmental factors influencing establishment of seedlings. Plots were randomly located in partial cut units harvested during the 1970-76 period in the mixed conifer/pinegrass and grand fir/big huckleberry plant communities.

On the average, partial cuts in the grand fir community were well stocked with about 2,200 seedlings or saplings per acre (all origins); whereas partial cuts in the mixed conifer community had considerably fewer seedlings or saplings (761 per acre), and some plots were understocked. About 77 percent of the seedlings in the grand fir type and 57 percent in the mixed conifer type were of natural postharvest origin. Planted seedlings made up only 6 percent of the seedlings in the grand fir type but accounted for 20 percent of the regeneration in the mixed conifer type where overall seedling density was less. Planted seedlings were dominant on more of the plots than their small numbers might suggest because of their greater height and good distribution.

Greater stocking was generally associated with increasing density of the overstory, but a heavy grass cover had a negative effect on establishment of seedlings. Other factors, such as aspect, slope, and elevation, had a positive or negative effect on stocking, depending on the species and community. Understocking also appeared to be related to low and irregular overstory density, lack of advance reproduction, or reproduction destroyed by logging, and heavy grass cover.

Usually, residual stand density after the seed cut should be reduced to the minimum level at which an acceptable amount of regeneration will be obtained. It appears that about 30 square feet of basal area per acre in the grand fir type and 50 square feet in the mixed conifer type distributed uniformly over the area should result in adequate stocking in most units. The disturbance to the forest floor from logging and slash disposal operations is sufficient to break up heavy, compact layers of litter and duff and to expose enough mineral soil to prepare a suitable seedbed. An exception may be in areas of continuous heavy pinegrass sod where additional site preparation may be needed.

Planting after the seed cut is primarily needed in the mixed conifer/pinegrass community to insure the establishment of regeneration before seedbeds are occupied by pinegrass or other seeded grasses. In the grand fir/big huckleberry type, where natural regeneration is more abundant and certain, planting may be needed as a supplemental practice to replace natural regeneration destroyed or damaged during the final overstory removal.

Blowdown of the residual overstory was about the same in both communities—0.3 to 0.4 tree per acre. The risk of blowdown can be reduced by marking leave trees that are fully crowned dominants or codominants (the most windfirm and also the best producers of seed) and by locating cutting boundaries where the risk of windthrow is low.

Contents

Introduction

During the early 1970's, many mixed conifer stands in the Blue Mountains of northeastern Oregon and southeastern Washington containing Rocky Mountain Douglas-fir and grand fir suffered mortality and damage from a severe outbreak of the Douglas-fir tussock moth.[1] Dead and damaged trees on many of these areas were salvaged, and natural and planted regeneration has since developed in some of these partial cuts. The availability of these partial cuts on a variety of sites provided an opportunity to evaluate the status of the regeneration and the factors affecting its establishment. The units sampled in a study conducted in 1980 and 1981 on the Umatilla and Wallowa-Whitman National Forests, are referred to as partial cuts rather than shelterwoods because in most of the units attacks by the tussock moth resulted in a patchy distribution of surviving overstory. The remaining trees also consisted of a variety of sizes and qualities, rather than only the best fully crowned trees that would be left in a planned shelterwood. This paper reports the results of that study.

[1] Scientific names are listed on page 14.

Objectives

The purposes of this study were to: (1) quantitatively evaluate the regeneration found on the partial cut units, (2) evaluate the condition of the residual overstory during the regeneration period, and (3) identify environmental factors associated with the presence or absence of regeneration. Specific objectives were to estimate: (1) success of regeneration in terms of stocking percentage and density (number per acre); (2) species composition of the regeneration; (3) stocking of regeneration of preharvest (advance) and postharvest (natural and planted) origin; (4) the relationship between regeneration and some measurable environmental variables, such as elevation, aspect, slope, and overstory density; and (5) survival and condition of the residual overstories.

Study Areas

Study areas (plots) were located in forests at midelevations of the Blue Mountains of northeastern Oregon and of southeastern Washington in the Umatilla and Wallowa-Whitman National Forests (fig. 1). Hall (1973) identified forest communities that occur in the study area or are similar. Identification of these plant communities is based on the dominant tree overstory and on shrubs, forbs, and grasses in the understory. Plots were located in two of these plant communities: (1) the mixed conifer/pinegrass community and (2) the grand fir/big huckleberry community. Being relatively stable, these plant communities can be placed within the habitat type classification, which stratifies environment by focusing on potential climax species. The mixed conifer/pinegrass community relates to at least three habitat types described for Idaho forest land: Douglas-fir/pinegrass (Daubenmire and Daubenmire 1968, Steele and others 1981), grand fir/pinegrass, and grand fir/white spirea (Steele and others 1981). Similarly, part of the grand fir/big huckleberry community type occurs on grand fir/blue huckleberry habitat types (Steele and others 1981).

The major tree species found in the mixed conifer/pinegrass community are ponderosa pine and Douglas-fir as seral species and grand fir as the climax species. In the grand fir/big huckleberry community, grand fir is the major tree species. If the site is moist enough, quantities of Engelmann spruce are present. Seral trees are ponderosa pine, Douglas-fir, and—depending on prior fire conditions—western larch and lodgepole pine.

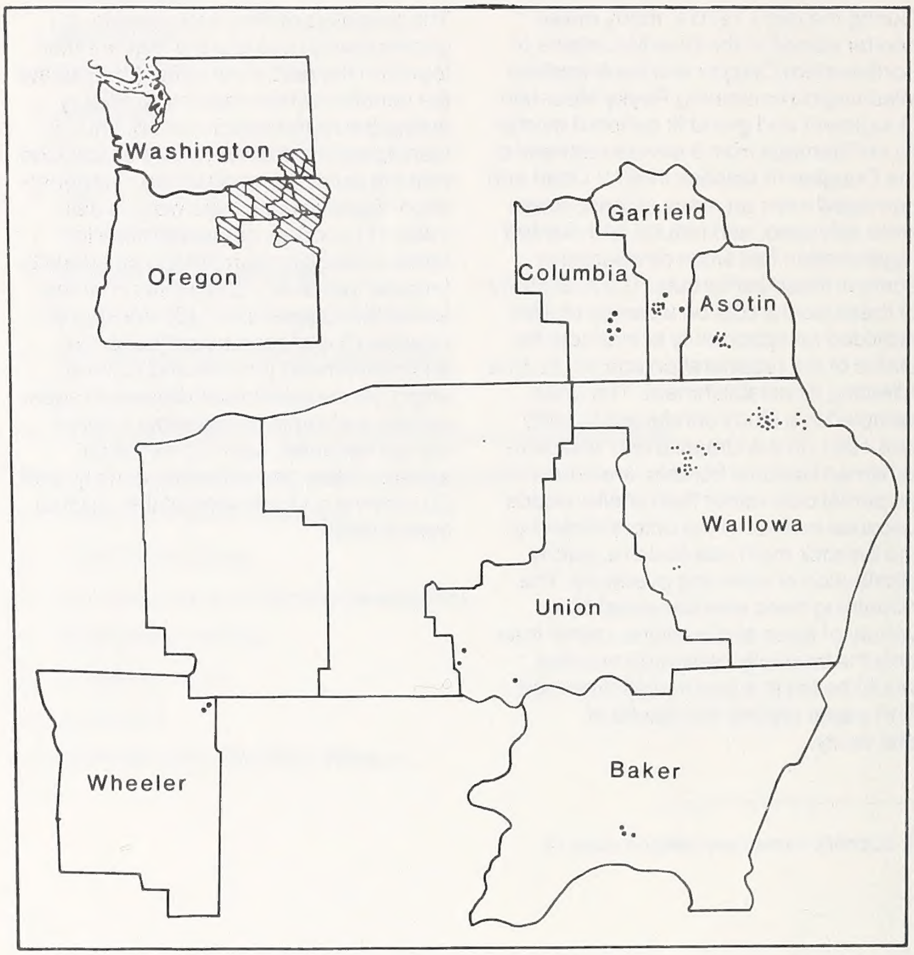

Figure 1.—Location of study areas in Oregon and Washington; one or two 10-acre plots were sampled in the vicinity of each dot.

Principal understory species of the mixed conifer/pinegrass community are common snowberry, white spirea, pinegrass, and elk sedge. Pinegrass often develops a more or less dense sod beneath the trees. Principal understory species of the grand fir/big huckleberry community are: big huckleberry, Utah honeysuckle, piper anemone, heartleaf arnica, wood strawberry, mountain sweet-root, and western meadowrue.

Predominant soils in these plant communities are immature Regosols (Vitrandepts) developed in the ash layer deposited from Mount Mazama or Glacier Peak. These are well-drained soils with silt loam A-C horizons over older buried soils or basalt (Wade 1975).

Some characteristics of the partial cuts sampled are given in table 1. In both plant communities, the residual overstory was similar in number of trees, basal area per acre, and average diameter. The major difference in the overstory between the two plant communities was species composition. In the mixed conifer/pinegrass community, 22 percent of the overstory was grand fir, 20 percent Douglas-fir, 43 percent ponderosa pine, 13 percent western larch, 2 percent lodgepole pine, plus a few Engelmann spruce. In the grand fir/big huckleberry community, there was considerably more grand fir (54 percent) and Engelmann spruce (16 percent) and fewer ponderosa pine (7 percent). In 61 partial cut units, slash was piled by machine and burned; in 14 units, it was not treated.

Table 1—Mean and range of some characteristics of partial cut units sampled in 2 plant communities in the Blue Mountains of northeastern Oregon and southeastern Washington

Characteristic	Unit of measure	Mixed conifer/pinegrass (38 plots) Mean	Range	Grand fir/big huckleberry (37 plots) Mean	Range
Elevation	Feet	4,780	4,200-5,300	4,874	4,200-5,400
Slope	Percent	5.1	0- 24	5.5	0- 16
Age	Years	5.7	4- 7	6.4	4- 12
Residual overstory:					
Trees per acre	Number	12.0	5- 31	14.0	3- 31
Average diameter	Inches	20.4	14.1- 25.3	19.4	13.9- 27.1
Basal Area	Square Feet	34.2	16- 67	33.4	7- 75
Crown closure	Percent	28.9	8- 54	26.9	8- 58
Seedbed: 1/					
Mineral soil	Percent	11.0	0- 44	9.0	0- 21
Litter	Percent	33.0	4- 72	41.0	4- 70
Slash	Percent	14.0	3- 30	14.0	8- 27
Litter and slash	Percent	38.0	13- 73	33.0	12- 62
Understory vegetation:					
Forbs	Percent	25.0	2- 49	15.0	0- 45
Shrubs	Percent	10.0	0- 37	10.0	0- 46
Grasses and sedges	Percent	28.0	2- 60	23.0	2- 62

1/ Total of all seedbed categories do not add to 100 percent because areas of some milacre plots are occupied by rocks and stumps.

Methods

Survey Design and Plot Selection

The mixed conifer and grand fir plant communities were considered separate populations. A record of units partially cut in 1976 or earlier in the two communities was obtained from the USDA Forest Service Regional Office (Pacific Northwest Region) in Portland, Oregon. Only units at least 4 years old were considered suitable for sampling so that reproduction would have had time to become established. The sampling unit was a square plot 10 acres in size. The total number of 10-acre plots in each plant community was then determined. In the mixed conifer community, 514 plots were available for sampling and 271 in the grand fir community.

We estimated that a total of about 75 plots could be sampled during the available time. Therefore, 38 plots were selected at random from the total number in the mixed conifer community and 37 from the total in the grand fir community. This resulted in a sampling intensity of about 7 and 14 percent, respectively. Candidate sample plots were rejected if the partial cut was seeded to trees or if it had been converted to nonforest uses.

Data Collection

A grid of 25 sample points (subplots) was centrally located on each 10-acre plot. Circular subplots (quadrats) were systematically spaced at 66-foot intervals on five parallel lines 66 feet apart containing five subplots each. At each of the 25 sample point locations in the plot, three concentric subplots (1-milacre, 4-milacre, and 0.0785-acre) were examined for presence of regeneration, associated environmental variables, and condition of residual overstory.

Information about the partial cut and the timber stand in which it was located was obtained from Ranger District records and from field observations. Information obtained was the plant community in which the plot was located; average elevation of the plot; timber type; date of harvest; slash treatment method and year of treatment; species planted and year of planting; subsequent cultural treatments; and general notes on size, growth, and distribution of regeneration, or damage. The plant community was verified by observation of adjacent uncut stands.

On each 1-milacre subplot, the total number of seedlings of each species was counted and recorded by origin. Regeneration was classified as of preharvest (advance) origin or of postharvest origin. Trees of postharvest origin were divided into 1- and 2-year-old seedlings from natural seed fall, seedlings 3 years old and older from natural seed fall, and planted trees. On each 4-milacre subplot, the species and origin (advance, natural postharvest, or planted) of the seedling most likely to dominate the subplot because of its size and vigor were recorded. Four-milacre subplots were used for data on dominant seedlings to reduce the probability of unstocked subplots. On each 0.0785-acre subplot, the species and diameter at breast height (d.b.h.) of all standing overstory trees, including trees that died during the regeneration period, were recorded plus the species, number, and d.b.h. of windthrown trees.

Planted trees were identified from information on species planted, date of planting, and spacing. In partial cuts where survival was high, regular rows of planted trees were clearly visible. Identification of planted trees was less certain when survival was low, but a count of whorls to check the age of a tree helped to identify planted trees.

The following environmental factors associated with each 1-milacre subplot were observed and recorded:[2] aspect, slope, condition of the seedbed (mineral soil, litter, slash), degree of burn, understory vegetation (forbs, shrubs, grasses), residual overstory density (basal area and percent crown closure), and presence or absence of animal damage.

Data Analysis

To illustrate the present status of reforestation, we summarized data in tables showing seedling numbers and stocking percentage of milacre subplots by species and origin for the plant communities. To determine the relationship between regeneration and environmental variables, we used stepwise multiple regression procedures to fit linear equations of the form $Y = b_0 + b_1X_1 + b_2X_2 + \ldots b_nX_n$ to the data. Dependent (Y) variables used were percentages of milacre subplots stocked and number of seedings per acre of the various species and origins, and the independent (X) variables were the environmental variables given in the appendix.[3] Curvilinear equations of the form $Y = a + b\,(1 - e^{-cX})^d$ were used to relate individual independent variables to percentage of stocked milacres because in some cases they described the relationship more realistically than did a linear model.

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[2] See appendix for details of procedures for measuring and coding the environmental factors.

[3] Subplots were considered stocked if they contained at least one seedling.

Results and Discussion

Regeneration Stocking and Density

Based on average seedling numbers and percentage of stocked milacres for all species and origins combined, regeneration was generally adequate in both plant communities. Plots in the grand fir/big huckleberry community averaged 2,201 seedlings per acre (all classes) compared with 761 in the mixed conifer/pinegrass community (table 2). About 50 percent of the milacre subplots were stocked with a seedling of any origin or species in the grand fir type and 37 percent in the mixed conifer type.

The majority of the seedlings in both communities became established after logging and were of natural origin (57 percent in the mixed conifer type and 77 percent in the grand fir type). Advance reproduction also was an important part of the regeneration, comprising about one-fifth of the total number of seedlings in each community. Distribution of advance reproduction was clumpy, occurring primarily in small areas undisturbed by logging activity.

One- and two-year-old seedlings also made up about one-fifth of the regeneration but, because of their small size and high mortality rate, are less important in overall regeneration than advance reproduction. The effect of these young seedlings was primarily to increase density of the regeneration rather than to greatly raise stocking percentages. For example, in the grand fir community, 1-and 2-year-old seedlings were the second largest group (511 per acre) (table 2), but stocking was increased more than 12 percent on only two of the 37 plots. Planted seedlings made up only 5 percent of all regeneration in the grand fir type but accounted for 19 percent of the seedlings in the mixed conifer community because there were fewer seedlings of other origins. Although there were relatively few planted seedlings, their uniform distribution resulted in a greater percentage of stocked milacres than might be expected by their small numbers (table 2).

The largest single component of the regeneration is natural postharvest seedlings 3 years and older (table 2). Because these partial cut units are only 5 to 6 years old, adequate seed fall must have occurred within 1 to 3 years after

Table 2—Average stocking percent and number of seedlings per acre of all species in 2 plant communities on partial cut units in the Blue Mountains of northeastern Oregon and southeastern Washington, by class of reproduction 1/

Class of regeneration	Mixed conifer/pinegrass			Grand fir/big huckleberry		
	Number of plots	Mean ± S.E. 2/	Range	Number of plots	Mean ± S.E. 2/	Range
			Stocking Percent			
Advance	38	11.3 ± 2.2	0- 60	37	16.3 ± 2.2	0- 48
Postharvest:						
1- and 2-year-old seedlings	38	6.7 ± 1.6	0- 48	37	14.6 ± 2.6	0- 68
3-year-old and older seedlings	38	14.5 ± 2.3	0- 52	37	28.8 ± 3.8	0- 92
Planted seedlings	35	13.7 ± 2.2	0- 36	35	11.4 ± 1.6	0- 36
All classes except 1- and 2-year-old seedlings	38	34.0 ± 3.2	0- 72	37	45.7 ± 3.7	8- 96
All classes	38	36.8 ± 3.4	4- 80	37	49.8 ± 3.7	12- 100
			Number of seedlings			
Advance	38	178 ± 43	0-1,120	37	378 ± 77	0- 2,000
Postharvest:						
1- and 2-year-old seedlings	38	120 ± 37	0-1,240	37	511 ± 187	0- 5,520
3-year-old and older seedlings	38	315 ± 71	0-1,160	37	1,192 ± 286	0- 7,800
Planted seedlings	35	148 ± 24	0- 400	35	120 ± 17	0- 360
All classes except 1- and 2-year-old seedlings	38	641 ± 98	0-2,920	37	1,691 ± 296	80- 8,280
All classes	38	761 ± 121	40-3,400	37	2,201 ± 448	120-12,800

1/ Based on 1-milacre subplots

2/ S.E. = standard error.

Table 3—Proportion of partial cut units stocked at various levels with 3-year-old and older advance and postharvest regeneration in 2 plant communities in the Blue Mountains of northeastern Oregon and southeastern Washington 1/

Community	Stocking			Trees per acre		
	At least	Plots	Proportion of total	At least	Plots	Proportion of total
	Percent	Number	Percent	Number	Number	Percent
Mixed conifer/pinegrass (38 plots)	20	29	0.76	200	30	0.79
	40	17	.45	400	23	.61
	60	4	.11	700	14	.37
	80	0	0	1,000	7	.18
				2,000	2	.05
				3,000	0	0
Grand fir/big huckleberry (37 plots)	20	34	.92	200	36	.97
	40	22	.59	400	30	.81
	60	11	.30	700	25	.68
	80	2	.05	1,000	19	.51
				2,000	12	.32
				3,000	6	.16

1/ Based on 1-milacre subplots.

logging for seedlings of this age to be present. The pattern of immediate establishment of natural regeneration after logging on most of these units is similar to that found on mixed conifer shelterwood units on the east slope of the Cascade Range (Seidel 1979b.). Because of the generally good seed production at frequent intervals in mixed conifer forests east of the Cascades, there is a good chance of obtaining a reasonable number of seedlings within a few years after logging.

Although the overall averages of seedling density and stocking indicate regeneration was generally successful, some units were not adequately stocked whereas others had a relative abundance of seedlings. For a clearer picture of the status of regeneration on these partial cuts, plots were grouped by the number and percentage that attained specific levels of stocking or density (table 3).

Depending on the definition of adequate stocking, the proportion of partial cuts successfully regenerated can be determined. For example, if 40-percent stocking of milacre quadrats is considered satisfactory, then only 45 percent of the mixed conifer/pinegrass units meet this standard compared with 59 percent of the grand fir/huckleberry units. On the basis of seedling density, 61 percent of the mixed conifer and 81 percent of the grand fir partial cuts had at least 400 seedlings per acre. Overstocking on these units was generally not a problem except on one plot in the grand fir type that had 12,800 seedlings per acre and two others that had more than 7,000 seedlings per acre.

Species Composition of Regeneration

Ponderosa pine, Douglas-fir, and grand fir were the three most common species in the mixed conifer/pinegrass type (table 4). The three major species in the grand fir community were grand fir, Engelmann spruce, and Douglas-fir. The primary difference in species composition between the two types was in the mixed conifer type; only a trace of Engelmann spruce occurred in the reproduction (0.3 percent), whereas in the grand fir type spruce was found on nearly 15 percent of the subplots.

Dominant Species

In addition to measurements of seedling stocking and density, from which the abundance and distribution of regeneration can be estimated, the species and origin of the largest or most vigorous seedling on each 4-milacre subplot were recorded. This gives an indication of the species most likely to predominate as the stand develops.

In the mixed conifer units, the three dominant species in the reproduction were ponderosa pine, Douglas-fir, and grand fir (table 5). Planted seedlings were dominant on 48 percent of the stocked subplots, and planted ponderosa pine was dominant on about 32 percent of the quadrats—the single largest species-origin combination. Advance reproduction was dominant on one-third of the stocked quadrats; it consisted primarily of grand fir and Douglas-fir.

In grand fir partial cuts, reproduction of natural postharvest origin was dominant on about 35 percent of the stocked quadrats compared with only 19 percent in the mixed conifer units (table 5). Advance reproduction dominated on 36 percent of the subplots, chiefly because of advance grand fir seedlings which were dominant on about 22 percent of the quadrats. In both these communities, planted seedlings assume greater importance as a stand component than their small numbers would suggest because of their uniform distribution.

Relation of Stocking and Density to Environmental Factors

The influence of observed environmental factors on regeneration and their relative importance in descriptions of present stocking and seedling density were determined by stepwise regression analyses. Some of the results of these analyses are presented in tables 6 and 7—the positive or negative relationship to stocking and density and the order in which variables appear in the equations.

It is apparent that the effect these variables have on stocking and density of regeneration depends on both the species and origin of reproduction and the plant community. For example, in the grand fir type aspect and elevation were positively related to reproduction, whereas in the mixed conifer community, there was little relationship (tables 6 and 7). The effect of most variables is logical and has a reasonable biological explanation.

Table 4—Average stocking of advance and postharvest regeneration on partial cut units in 2 plant communities in the Blue Mountains of northeastern Oregon and southeastern Washington, by species 1/

Community and regeneration	Grand fir	Douglas-fir	Western larch	Engelmann spruce	Ponderosa pine	Lodgepole pine
			Stocking percent ± S.E. 3/			
Mixed conifer/pinegrass:						
Advance regeneration	5.8 ± 1.3	2.7 ± 0.8	0.3 ± 0.2	0.1 ± 0.1	2.5 ± 1.1	1.5 + 1.3
Postharvest seedlings 2/--						
3-year-old and older	5.1 ± 1.4	8.1 ± 1.4	2.5 ± 1.0	0.2 ± 0.2	12.8 ± 1.7	2.2 ± 1.4
1- and 2-year old	2.2 ± 0.7	2.4 ± 0.7	0.1 ± 0.1	0 ± --	1.6 ± 0.5	1.4 ± 0.9
All classes	11.2 ± 2.2	12.1 ± 1.8	3.1 ± 1.0	0.3 ± 0.3	15.8 ± 1.8	2.8 ± 1.8
Grand fir/big huckleberry:						
Advance regeneration	11.8 ± 1.8	1.0 ± 0.3	1.5 ± 0.7	3.4 ± 1.1	0.1 ± 0.1	0.5 ± 0.4
Postharvest seedlings 2/--						
3-year-old and older	15.1 ± 3.2	10.1 ± 2.1	3.1 ± 0.8	9.3 ± 1.1	7.1 ± 1.5	4.0 ± 1.6
1- and 2-year-old	7.0 ± 2.0	2.6 ± 0.8	1.1 ± 0.4	4.6 ± 1.5	1.1 ± 0.5	2.2 ± 1.5
All classes	26.6 ± 3.5	13.0 ± 2.5	5.4 ± 1.3	14.5 ± 2.4	8.1 ± 1.7	5.2 ± 2.0

1/ Based on 1-milacre subplots.

2/ Includes natural and planted regeneration.

3/ S.E. = standard error.

Table 5—Stocked subplots by species and origin of dominant seedlings in 2 plant communities on partial cut units in the Blue Mountains of northeastern Oregon and southeastern Washington 1/

Origin of seedlings	Grand fir	Douglas-fir	Western larch	Englemann spruce	Ponderosa pine	Lodgepole pine	Total
				Percent			
Mixed conifer/pinegrass:							
Advance	14.8	9.1	1.2	0.2	6.6	1.2	33.1
Natural postharvest	8.5	4.8	1.2	--	3.6	.5	18.6
Planted	.5	14.3	.8	--	32.4	.3	48.3
Total	23.8	28.2	3.2	.2	42.6	2.0	100.0
Grand fir/big huckleberry:							
Advance	21.6	1.9	2.5	8.2	.7	1.2	36.1
Natural postharvest	13.1	4.4	2.3	8.2	2.5	4.0	34.5
Planted	2.6	9.7	--	3.7	12.8	.6	29.4
Total	37.3	16.0	4.8	20.1	16.0	5.8	100.0

1/ Based on 4-milacre subplots; 1- and 2-year-old seedlings included.

Table 6—Positive and negative correlations of variables and the order in which they appeared in regression equations describing stocking of regeneration in 2 plant communities on partial cut units in the Blue Mountains of northeastern Oregon and southeastern Washington[1/]

Species or origin	Aspect	Slope	Elevation	Mineral soil	Litter	Slash	Burn	Forbs	Shrubs	Grass	Basal area	Crown closure	Trees per acre	Quadratic mean diameter	Animal damage	Gopher activity	Age	R^2	Standard error of stocking percent
Grand fir/big huckleberry:																			
All regeneration	+6		+1	-2				+7	+3	-5				-4				0.71	12.5
All natural regeneration	+6	-7	+1	-3					+2	-5				-4				.78	10.9
3-year-old and older seedlings	+7		+1	-5			+8	+2	+4	-6				-3				.66	13.7
1- and 2-year-old seedlings		+2	+3		+4				+5				+1	-6	+8		-7	.73	6.6
Natural postharvest			+1	-6				+2	+4			+5		-3				.65	13.4
Postharvest grand fir	+4	+3								-1				-5	+2			.70	9.1
All grand fir	+2					+7	+6		+4	-1			-5		+3			.73	10.4
All Douglas-fir			+3					+2	+8	+5	-4	+1		+7	+6			.72	8.7
All larch	+4	-3	+6			+8		+1	+2			-7		+9			-5	.69	5.2
All spruce	+3		+1	-4	+2													.51	9.6
All ponderosa pine			-2	-1	-4		+3	-6		+5					+7			.47	8.2
Mixed conifer/pinegrass:																			
All regeneration									+1	-4		+2	-5		+3			.69	12.4
All natural regeneration						+4		-3	+2	-6		+1			+5			.79	10.3
3-year-old and older seedlings	-4			-5					+2	-3		+2	-6					.62	9.4
1- and 2-year-old seedlings					+6			-3	+2			+1		-4	-5			.42	8.3
Natural postharvest						+3		-6	+1	-5		+2		-4				.64	10.4
Postharvest grand fir	-5								+2	-3		+1					-4	.52	7.0
All grand fir								-7		-6	+4	+1	-2		+5	-3	-8	.72	7.9
Postharvest Douglas-fir					+4			+3		-1			+2					.23	8.7
All Douglas-fir				-5	+3			+2				+1					+4	.30	10.2
All larch			-5						+1	-2	-3			+4				.59	4.1
All ponderosa pine		+3	-5							-2	-4				+1			.74	6.3

1/ Numbers indicate the order in which variables entered the regression equation. Only variables that accounted for the major portion of the variation in stocking percent are given. Variables were excluded if they failed to raise R^2 values by at least 3 percent.

Table 7—Positive and negative correlations of variables and the order in which they appeared in regression equations describing density of regeneration in 2 plant communities on partial cut units in the Blue Mountains of northeastern Oregon and southeastern Washington 1/

Species or origin	Aspect	Slope	Elevation	Mineral soil	Litter	Slash	Burn	Forbs	Shrubs	Grass	Basal area	Crown closure	Trees per acre	Quadratic mean diameter	Animal damage	Gopher activity	Age	R^2	Standard error of seedling density
Grand fir/big huckleberry:																			
All regeneration	+6		+1	-4	+7			+8	+2	-5				-3				0.69	947
All natural regeneration	+6		+1	-4	+7				+2	-5				-3				.67	953
3-year-old and older seedlings	+7		+1	-5			-4		+3	-6				-2				.53	939
1- and 2-year-old seedlings		+2	+4		+3			+5		-6			+1					.63	206
Natural postharvest	+6		+1				-4		+3	-5				-2				.56	1013
Postharvest grand fir	+4	+2								-3			-6		+1		-5	.52	452
All grand fir	+2									-1			-4		+3		-5	.50	577
All Douglas-fir			+3				+5	+2		+4		+1						.57	172
All larch		-3	+8			+10		+2	+1	+5		-9	+4	+6			-7	.69	68
All spruce	+6		+5		+3								+2			-4	+1	.37	1016
All ponderosa pine			-3	-2	-4		+1											.56	115
Mixed conifer/pinegrass:																			
All regeneration									+2		+6	+1	-5	-4	+3			.65	483
All natural regeneration						+4		-3	+2	-5	+1							.63	504
3-year-old and older seedlings					-6	+2	-4				+1				+5	-3		.56	316
1- and 2-year-old seedlings		+3	-2									+1		-4	-5			.42	184
Natural postharvest						+4			+2			+1		-3				.50	436
Postharvest grand fir						+3						+1				-2		.40	252
All grand fir											+5	+1	-4	-3			-2	.53	311
Postharvest Douglas-fir								+2				+1	+3					.28	145
All Douglas-fir		+3						+2				+1						.33	164
All larch			-2						+1	-3	-5			+4				.63	42
All ponderosa pine									+3				+2		+1			.58	244

1/ Numbers indicate the order in which variables entered the regression equation. Only variables that accounted for the major portion of the variation in density of seedlings are given. Variables were excluded if they failed to raise R^2 values by at least 3 percent.

Exceptions are the negative correlation of mineral soil to regeneration in the grand fir type and the positive correlation of animal damage to regeneration in both communities. The negative correlation of mineral soil to regeneration was not expected because studies have shown mineral soil to be the most favorable seedbed for natural regeneration (Seidel and Cooley 1974, Seidel 1979a). Although mineral soil is an excellent seedbed for natural regeneration, many seedlings (especially true fir) do become established in light to medium litter layers (one-fourth to one-half inch deep). Also, light amounts of slash provide a favorable environment for seedling establishment because of the protection offered against temperature extremes. Therefore, it is neither necessary nor desirable to completely remove all litter and slash from the seedbed. Generally, enough disturbance is caused by logging and slash disposal to provide a receptive seedbed, except possibly in areas of continuous heavy pinegrass sod. A positive correlation of animal damage and regeneration also was not expected, although disturbance as a result of livestock and big game activity may have resulted in a more favorable seedbed. Consumption of understory vegetation (especially grass) by animals could also reduce competition for water and nutrients and thus increase survival of seedlings.

Similar to stocking in shelterwood units in the Cascade Range, stocking of regeneration decreased as grass cover increased in both plant communities (fig. 2). Although the equations relating milacre stocking to grass cover were highly significant (P<0.01) for both communities, there was still too much unexplained variation for use as prediction equations. The equations do indicate, however, that heavy amounts of grass can reduce the chance of successful establishment of tree seedlings.

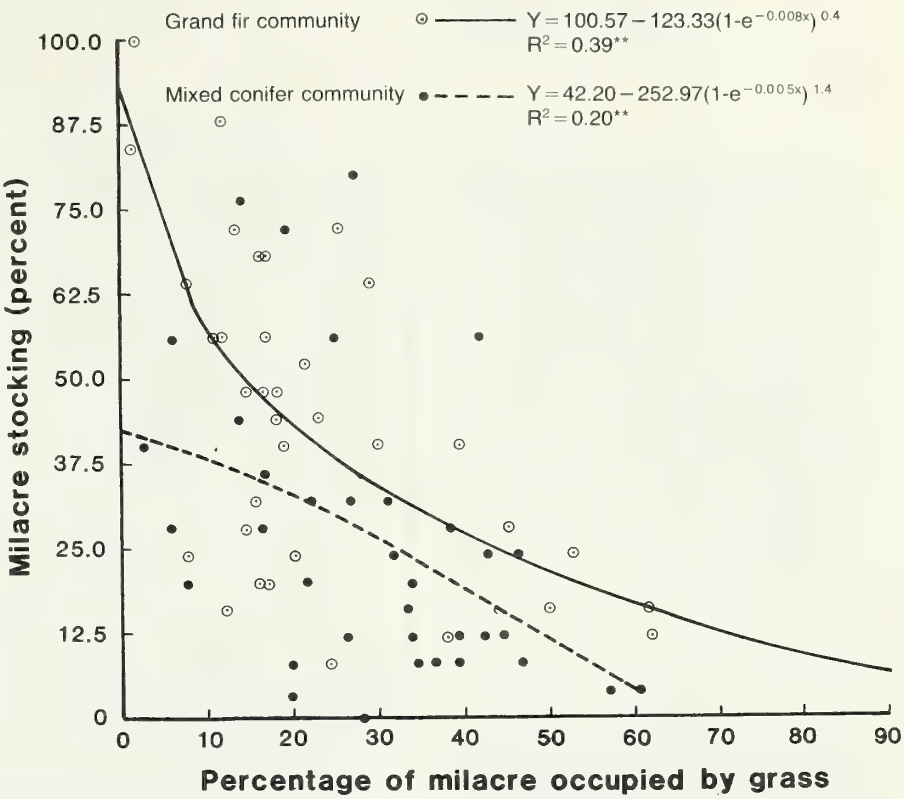

Figure 2.—Relationship between amount of grass cover and milacre stocking of natural regeneration in the grand fir and mixed conifer plant communities in the Blue Mountains of northeastern Oregon and southeastern Washington; ** = significant at the 1-percent level.

Residual Stand Density and Regeneration

Both basal area and crown closure were positively correlated with density and stocking of natural regeneration, especially in the mixed conifer/pinegrass community where crown closure entered as the first or second variable in nearly all the equations (tables 6 and 7).

The equations describing the relationship of basal area or overstory crown closure to stocking of natural regeneration, although highly significant (P<0.01), are not accurate enough to be used as predictors of expected regeneration (figs. 3 and 4). In addition, these equations were not tested against an independent set of data. They do, however, give some idea of the general trend of reproduction as stand density varies and the range of stand densities where successful natural regeneration can be expected.

Overstory crown closure was better correlated with milacre stocking (fig. 4) than was basal area (fig. 3), and for both density measures the relationship was stronger in the mixed conifer/pinegrass community.

In both plant communities, stocking of milacres increased as stand density increased, and there was a large amount of unexplained variation in stocking. At lower density levels (less than 56 square feet of basal area per acre or 50-percent crown closure), milacre stocking was greater in the grand fir/big huckleberry type than in the mixed conifer/pinegrass type for a given level of stand density (figs. 3 and 4). In general, residual stand density after the seed cut should be reduced to the minimum level at which an acceptable amount of regeneration will be obtained. Because of the large amount of unexplained variation associated with these equations, they should be used only as crude indicators of possible desirable stand density levels. From the data obtained from these partial cuts, it appears that if at least 40-percent stocking of milacre plots is desired, then a basal area of about 30 square feet per acre in the grand fir/big huckleberry type and about 50 square feet per acre in the mixed conifer/pinegrass type should result in adequate stocking on most units. Data from a shelterwood study on the Starkey Experimental Forest in eastern Oregon suggest that adequate natural regeneration can be obtained from lower stand densities if fully crowned dominant and codominant seed trees are distributed uniformly over the area.[4]

[4] Data on file at Silviculture Laboratory, Bend, Oregon.

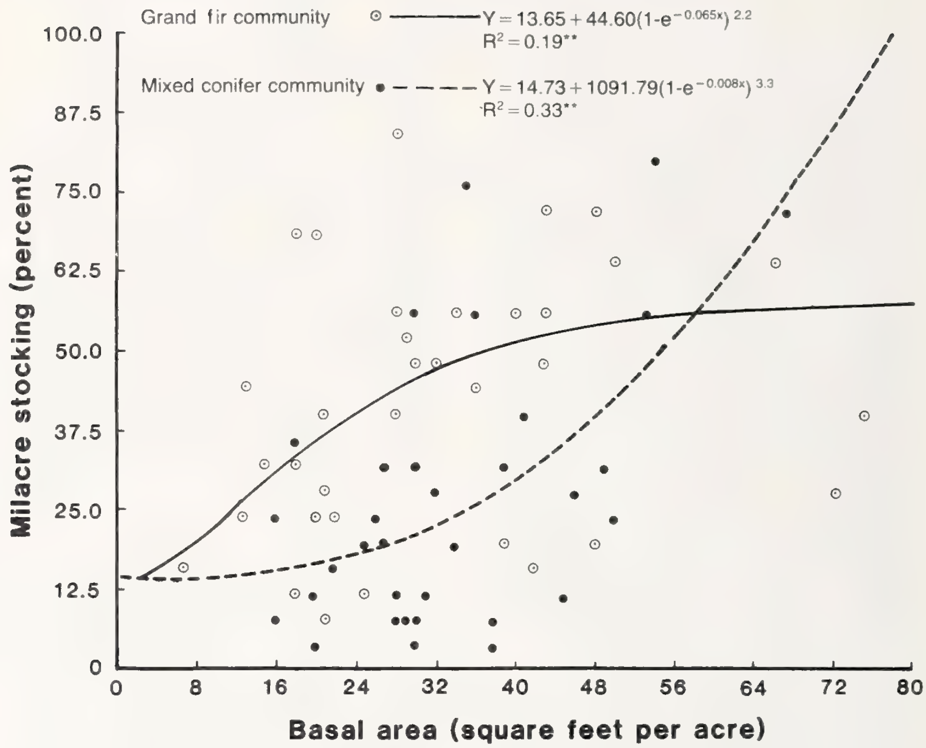

Figure 3.—Relationship between basal area and milacre stocking of natural regeneration in the grand fir and mixed conifer plant communities in the Blue Mountains of northeastern Oregon and southeastern Washington; ** = significant at the 1-percent level.

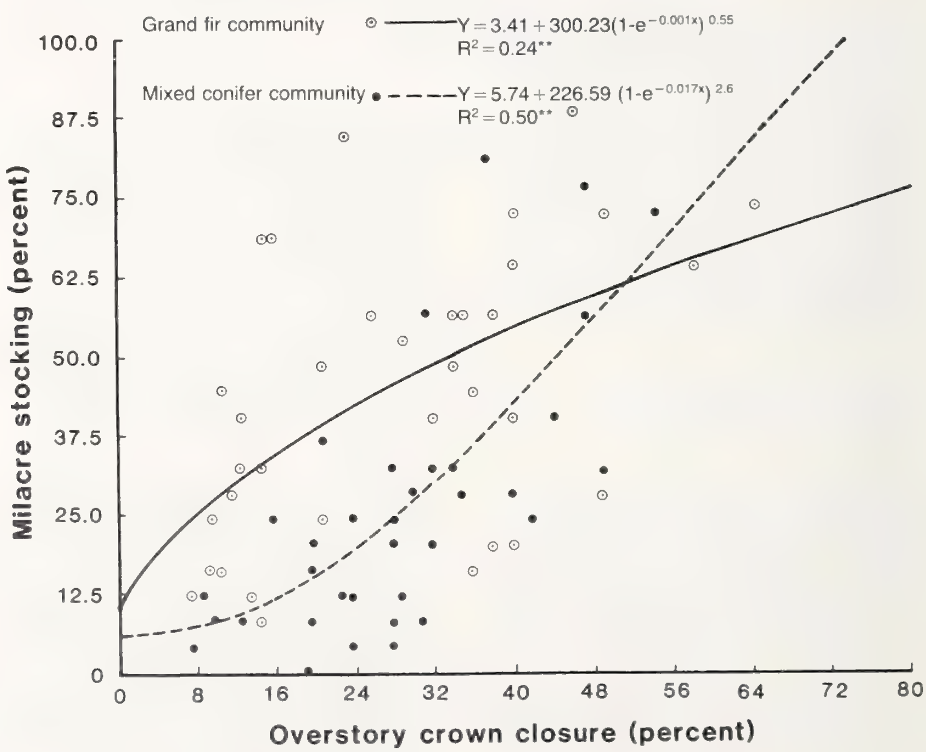

Figure 4.—Relationship between overstory crown closure and milacre stocking of natural regeneration in the grand fir and mixed conifer plant communities in the Blue Mountains of northeastern Oregon and southeastern Washington; ** = significant at the 1-percent level.

Impact of Planted Seedlings

Planted seedlings are of greater importance for regeneration in units where natural reproduction is light. Planted seedlings made up only 5 percent of the total number of seedlings in the grand fir community compared with 19 percent in the mixed conifer type where natural regeneration was not as abundant.

As discussed previously, however, because of their good distribution planted seedlings contribute more than their small numbers might suggest. If a unit is considered adequately stocked when 40 percent of the milacre quadrats contain at least one seedling, then planting increased the stocking above this level on only 3 percent of the grand fir/big huckleberry units compared with 24 percent of the mixed conifer/pinegrass units.

The results of this study show that the need for planting depends on the plant community and other factors such as how rapidly understory vegetation occupies disturbed areas. The most likely candidates for planting immediately after the seed cut are shelterwood units in mixed conifer/pinegrass communities where there is a good chance of the seedbed being occupied by pinegrass and other vegetation before natural tree seedlings have had a chance to become established. On many of these units, both planted and natural seedlings are subject to severe competition not only from pinegrass but also from direct seeded grasses such as timothy and orchardgrass. On the other hand, in grand fir/big huckleberry types, especially on north slopes, where abundant natural regeneration is likely to occur, the most efficient use of planting is to increase stocking if removal of the residual overstory has reduced stocking below minimum standards.

The species planted should be native to the plant community. In the mixed conifer/pinegrass type, ponderosa pine and Douglas-fir are good species to plant. Douglas-fir is suitable for north and east slopes, whereas ponderosa pine should be favored on warmer south and west aspects. In the grand fir/huckleberry types, consideration should also be given to planting grand fir and Engelmann spruce—especially on higher elevation north to east slopes where these species naturally occur.

Overstory Mortality

Mortality of the residual overstory after partial cutting was about the same in both communities. In the grand fir type, about 16 percent of the overstory was lost—an average of 0.4 tree per acre blown down and 1.8 tree per acre standing dead. In the mixed conifer community, 13 percent of the trees were lost—0.3 tree per acre to windthrow and 1.3 per acre standing dead.

Blowdown can be a problem when the shelterwood system is used or partial cuts are made in unmanaged old-growth stands because trees growing at high densities have not developed the windfirmness needed to resist greater stresses from wind after heavy partial cuts. The risk of blowdown can be reduced by leaving dominant or codominant, full-crowned trees which are the most windfirm and also the best seed producers (Gordon 1973). In addition, use of guidelines for locating cutting boundaries and for identifying topographic situations where the risk of blowdown is high can decrease the mortality from windthrow. Alexander (1964) has prepared guidelines for spruce-fir forests in Colorado that may be useful in the high elevation mixed conifer forests of eastern Oregon and Washington.

Conclusions and Recommendations

The results of this study indicate that a combination of advance reproduction, natural regeneration, and planted seedlings generally resulted in satisfactory stocking on most of the partial cut units. Regeneration was usually abundant in the grand fir/big huckleberry community, because of many grand fir, Douglas-fir, and Engelmann spruce seedlings of natural origin. Most of the understocked units were in the mixed conifer/pinegrass community and appeared to be related to at least one of the following factors: low and irregular overstory density, lack of advance reproduction or reproduction destroyed in logging, and heavy grass cover.

Using the shelterwood system where the residual overstory is composed of healthy dominant and codominant trees spaced uniformly over the area should result in adequate numbers of natural seedlings if a basal area of about 30 square feet per acre is left in the grand fir type and about 50 square feet per acre in the mixed conifer type. Where problems with animal damage to natural or planted regeneration are expected, an effort should be made to save as much of the advance reproduction as possible if it is sufficiently vigorous to respond to release. Even though suppressed for many years, vigorous, full-crowned trees will respond to release (Seidel 1977). Saving the advance reproduction or established regeneration requires good coordination between timber and fuels management staffs and the skillful application of logging techniques designed to preserve the established reproduction such as those suggested by Gottfried and Jones (1975).

Planting is needed after partial cutting or when the shelterwood system is used, primarily in the mixed conifer/pinegrass community to insure the establishment of regeneration before seedbeds are occupied by grass and other vegetation. Often cutting units were seeded immediately to orchardgrass, timothy, or

other introduced grasses which, together with the native vegetation, can inhibit or exclude natural tree regeneration. In the grand fir/big huckleberry type, where natural regeneration is more abundant and certain, planting seems best suited as a supplemental practice to replace natural regeneration destroyed or damaged during the final overstory removal. Planting is not needed in units that are already fully stocked or overstocked with natural regeneration. Ponderosa pine and Douglas-fir are the preferred species to plant in these communities, but they should not be planted on sites where, because of snow and ice or soil conditions, the logical species to plant are the naturally occurring grand fir or Engelmann spruce. Such cold and moist sites are indicated by the abundant seedlings and saplings of these species already present.

Metric Equivalents

1 acre = 0.405 hectare
1 foot = 0.3048 meter
1 inch = 2.54 centimeters
1 mile = 1.61 kilometers
1 square foot = 0.0929 square meter
1 square foot/acre = 0.2296 square meter/hectare
1 tree/acre = 2.47 trees/hectare

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Appendix

Independent (X) variables used in regression analyses:

1. Elevation.—The average elevation of the plot to the nearest 10 feet as measured with an altimeter.

2. Aspect.—One of eight compass points measured on each subplot. The method proposed by Day and Monk (1974) was used to code the aspect, and the following values were assigned to compass directions: N - 14; NE - 15; E - 11; Se - 7; S - 3; SW - 2; W - 6; NW - 10. Average coded value of the 25 subplots was used in analyses.

3. Slope.—Percentage slope of each subplot was measured with a clinometer and coded as follows: 0-9 percent, 0; 10-19 percent, 1; 20-29 percent, 2; 30-39 percent, 3; etc. Average coded value of subplots was used.

4. Mineral soil.—The percentage of each subplot containing mineral soil was estimated, coded in the same way as slope values, and averaged.

5. Litter.—The percentage of each subplot covered with litter was estimated, coded in the same way as slope values, and averaged.

6. Slash.—The percentage of each subplot covered with slash was estimated, coded in the same way as slope values, and averaged.

7. Degree of burn.—Estimated on each subplot and coded as: None, 0; light, 1; medium, 2; heavy, 3. Averaged coded value was used in analyses. Degree of burn is defined as: None—no visible effect of fire; light—fire charred the surface of the forest floor but did not remove all the litter layer; medium—fire removed all the litter layer and some of the duff; heavy—fire removed all the litter and duff and imparted a color to the mineral soil.

8. Forbs.—The percentage of each subplot covered with forbs was estimated, coded in the same way as slope values, and averaged.

9. Shrubs.—The percentage of each subplot covered with shrubs was estimated, coded in the same way as slope values, and averaged.

10. Grasses and sedges.—The percentage of each subplot covered with grasses and sedges was estimated, coded in the same way as slope values, and averaged.

11. Basal area.—The overstory basal area at each subplot was measured with a 10- factor angle gage and averaged for use in analyses.

12. Crown closure.—The overstory crown closure was measured with a spherical densiometer at each subplot by Strickler's (1959) method. Average value of the 25 subplots was used in analyses.

13. Overstory trees per acre.—The numbers of standing overstory trees (living and dead) and blown down trees were recorded on 0.0785-acre subplots at each of the 25 sample points, averaged, and converted to a per-acre basis.

14. Overstory average diameter.—The diameters at breast height of living and dead standing trees and blown down trees on each 0.0785-acre subplot were measured to the nearest inch and averaged.

15. Animal damage.—The presence or absence of damage such as browsing or trampling by animals other than gophers (primarily deer, elk, or cattle) was recorded for each subplot. The percentage of subplots showing such damage was used in the analyses.

16. Gopher activity.—The presence or absence of gopher activity as indicated by mounds was recorded for each subplot. The percentage of subplots showing such activity was used in the analyses.

Common and Scientific Names [5]

Plants

Common name	Scientific name
Trees:	
Douglas-fir (Rocky Mountain)	*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco
Engelmann spruce	*Picea engelmannii* Parry ex Engelm.
Grand fir	*Abies grandis* (Dougl. ex D. Don) Lindl.
Lodgepole pine	*Pinus contorta* Dougl. ex Loud.
Ponderosa pine	*Pinus ponderosa* Dougl. ex Laws.
Western larch	*Larix occidentalis* Nutt.
Shrubs:	
Big huckleberry	*Vaccinium membranaceum* Dougl. ex Hook.
Blue huckleberry	*Vaccinium globulare* Rydb.
Common snowberry	*Symphoricarpos albus* (L.) Blake
Utah honeysuckle	*Lonicera utahensis* Wats.
White spirea	*Spiraea betulifolia* Pall.
Forbs:	
Heartleaf arnica	*Arnica cordifolia* Hook.
Mountain sweet-root	*Osmorhiza chilensis* H. & A.
Piper anemone	*Anemone piperi* Britt.
Western meadowrue	*Thalictrum occidentale* Gray
Wood strawberry	*Fragaria vesca* var. *bracteata* (Heller) Davis
Grasses and sedges:	
Elk sedge	*Carex geyeri* Boott
Orchardgrass	*Dactylis glomerata* L.
Pinegrass	*Calamagrostis rubescens* Buckl.
Timothy	*Phleum pratense* L.

Insect

Douglas-fir tussock moth	*Orgyia pseudotsugata* (McDunnough)

[5] Sources for nomenclature: trees—Little (1979); shrubs, forbs, and grasses and sedges—Garrison and others (1976); and insects—Furniss and Carolin (1977).

Seidel, K. W.; Head, S. Conrade. Regeneration in mixed conifer partial cuttings in the Blue Mountains of Oregon and Washington. Res. Pap. PNW-310. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1983. 14 p.

A survey in the Blue Mountains of northeastern Oregon and southeastern Washington showed that, on the average, partial cuts in the grand fir/big huckleberry community were well stocked with a mixture of advance, natural postharvest, and planted reproduction of a number of species. Partial cuts in the mixed conifer/pinegrass community had considerably fewer seedlings; some plots were understocked. Much of the understocking appeared to be related to low and irregular overstory density, lack of advance reproduction, reproduction destroyed by logging, and heavy grass cover.

Keywords: Regeneration (stand), partial cutting, regeneration (artificial), regeneration (natural), mixed stands, Blue Mountains (Oregon), Blue Mountains (Washington).

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